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Inventor: Yufu Wang.

Chinese Patent
Patent Number: 01140014.5 Data of Patent Nov. 20, 2001

[54] BOOST CONVERTER WITH LOWER INTER-PHASE RECIFIER PARALL COMPENSETING THREE-PHASE POWER FACTOR CORRECTION

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[73] Assignee:

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[22] Field: Nov. 20 2001

[51] Int. Cl. H02M 1/12

[52] U. S. Cl. 363/84;363/89;323/225

[58] Field of search 363/84;363/89;323/225

[56] References Cited

5,886,891	3/1999	Jiang	363/84
6,043,997	3/2000	He	363/84
6,043,997	3/1999	jiang	363/84

Abstract—The auxiliary compensating circuit, which is in parallel with a common three-phase bridge rectifier with lower filtering capacitance, is composed a single boost converter and a lower inter-phase rectifier which includes three bi-direction switches and a three-phase bridge rectifier. In each $\pi/6$, the switches, in turns, cuts off one with higher absolute value of the two phases being at same polarity, the phase with lower absolute value is forced to conduct to the third phase and giving out the current with suitable waveform by the boost converter, the current of the phase with higher absolute value is decreased, the current waveform of the third phase, the output voltage and current of the whole rectifier are not changed. In this way, only the distribution of the current between the phases is changed and about 22% amount of the power is processed, the THD is cut down from 0.3 to 0.03 typically.

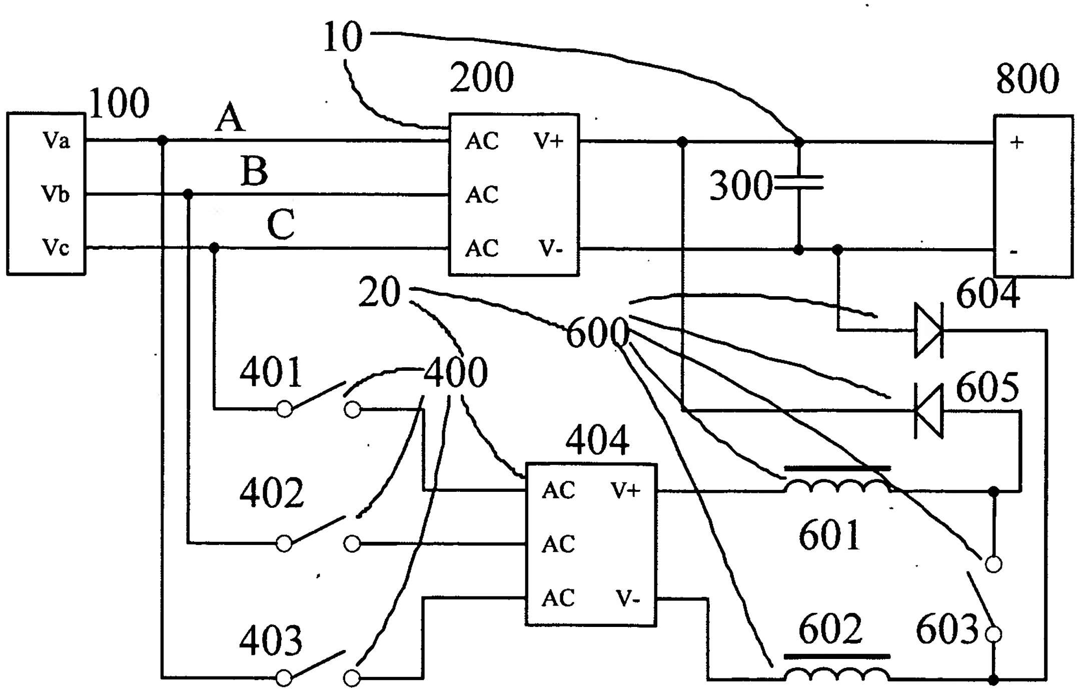

Fig. 1

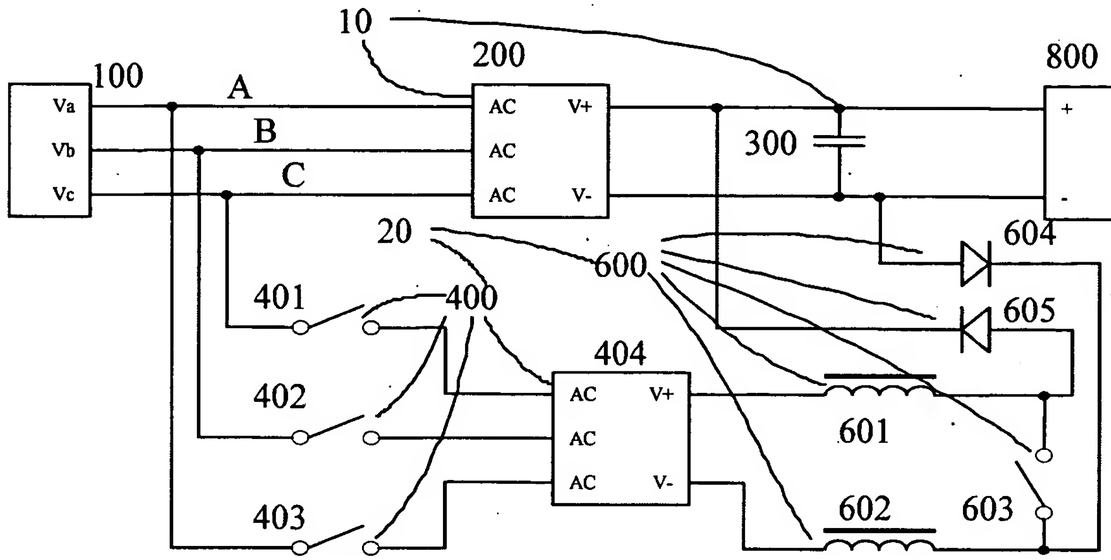
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FIG. 2

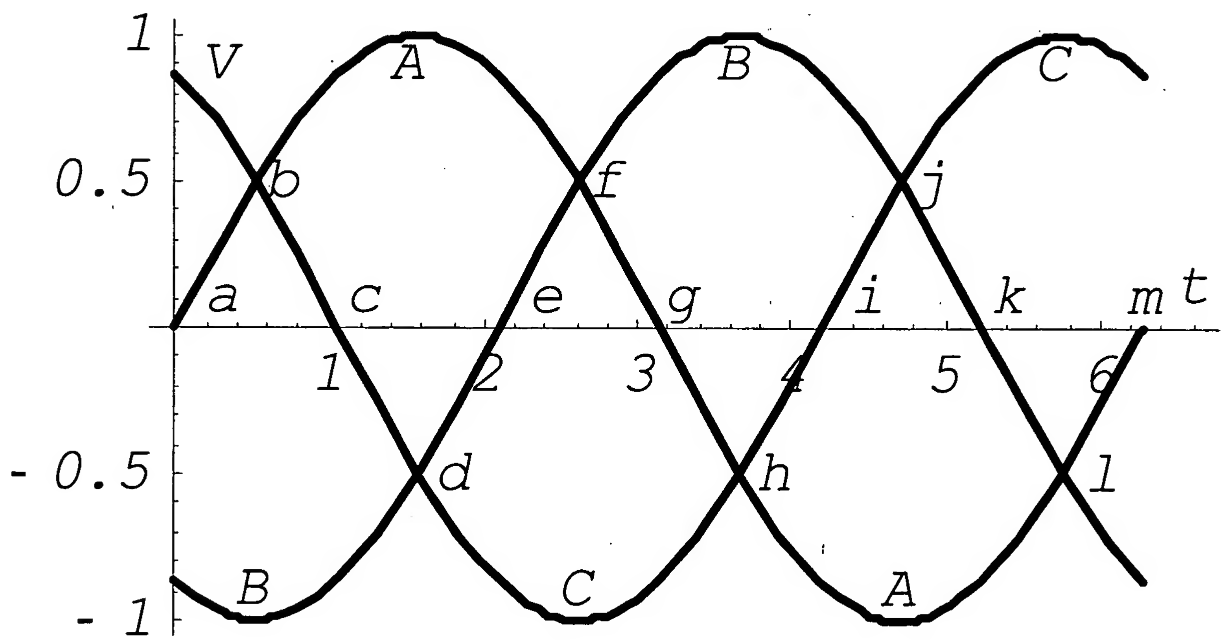
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FIG. 3

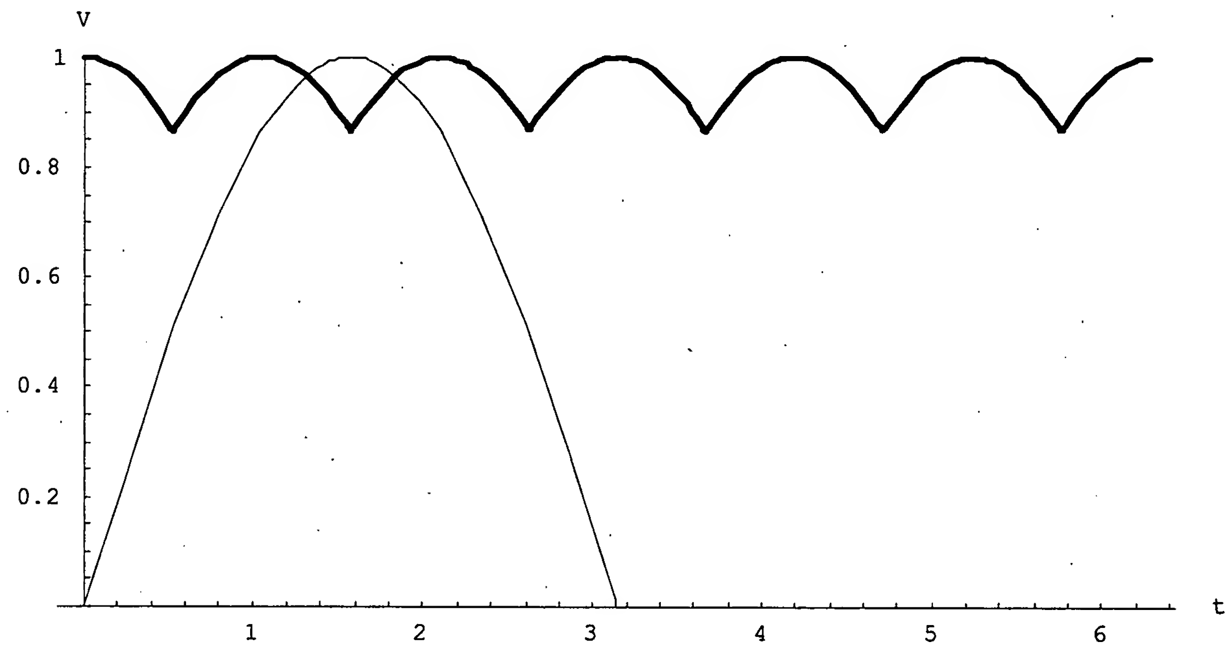
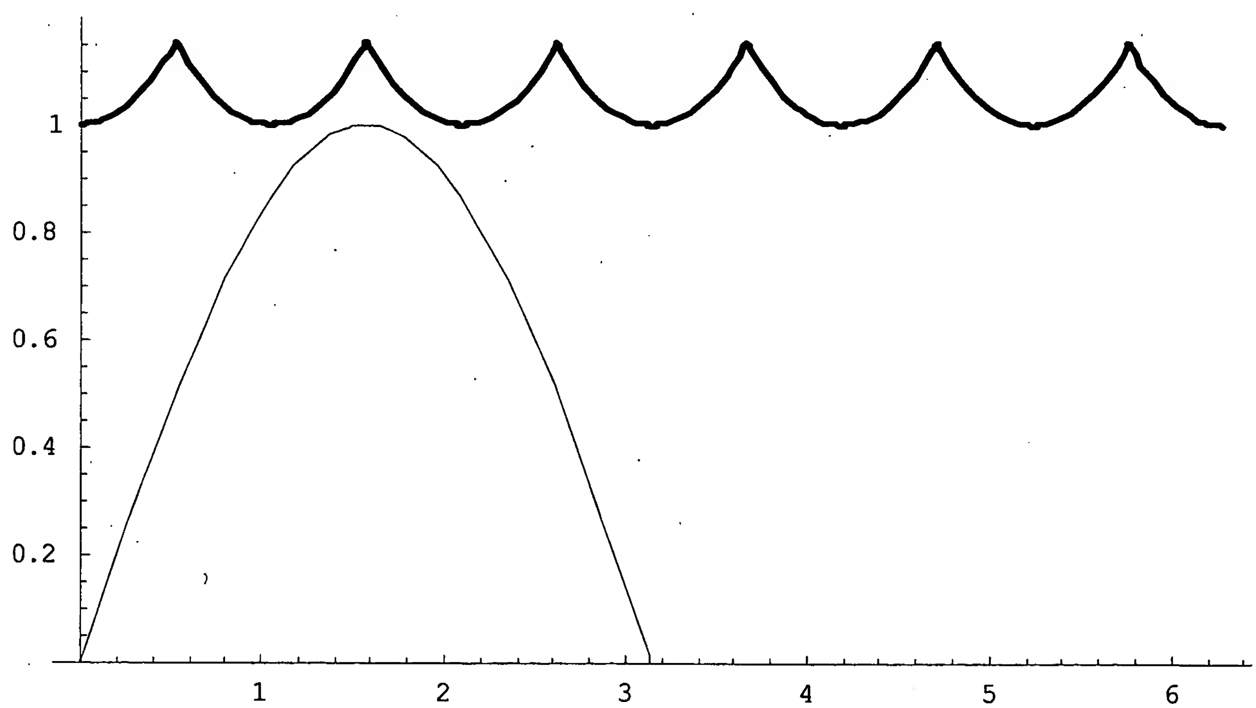


FIG. 4



FIQ. 5

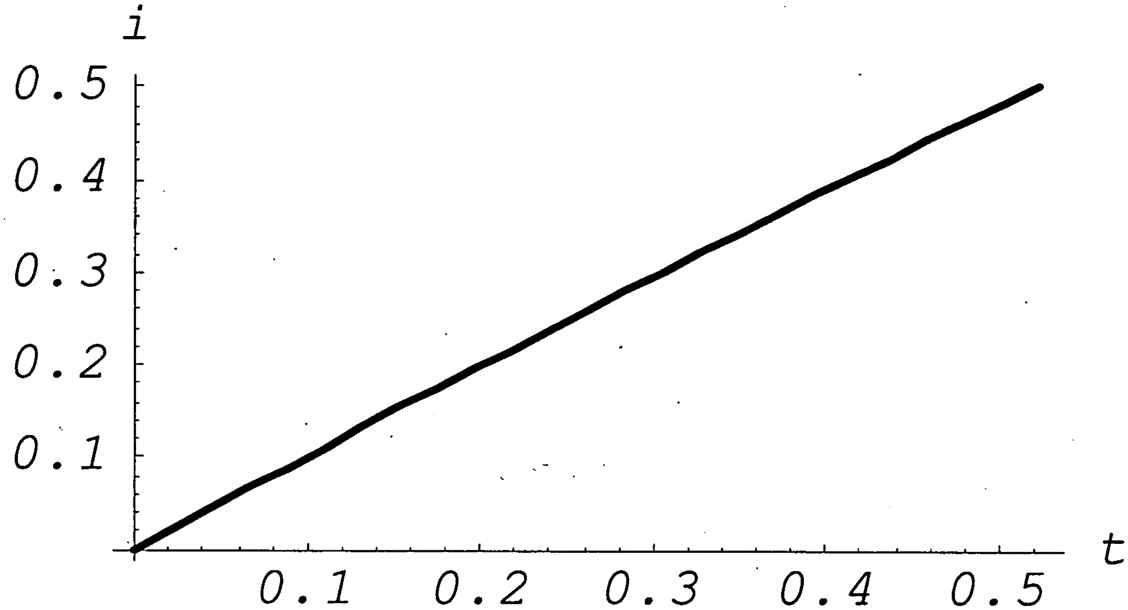
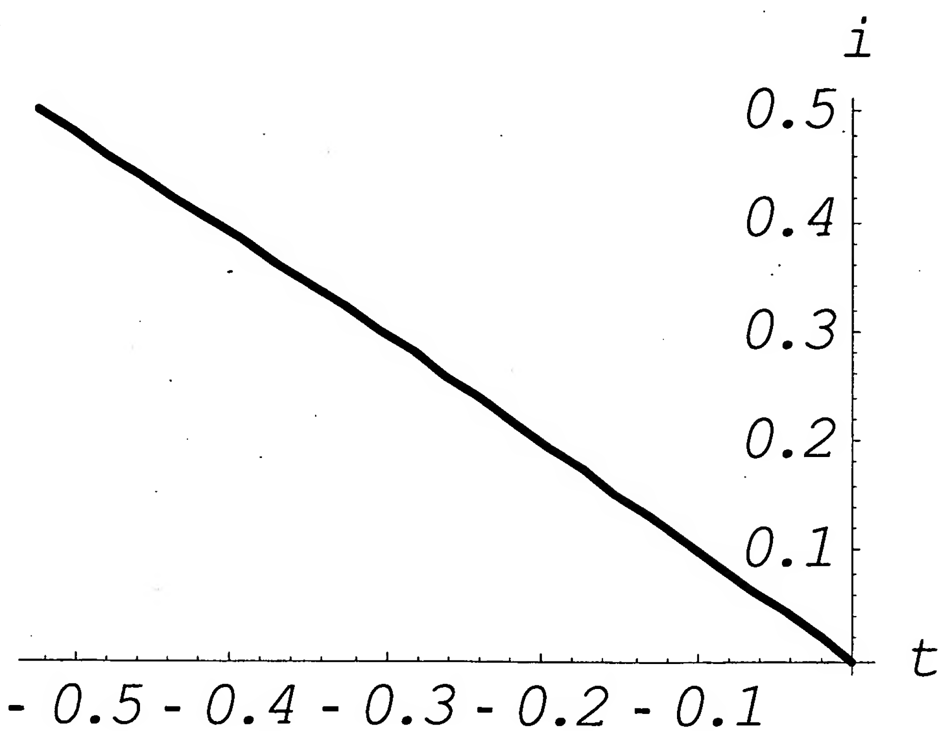
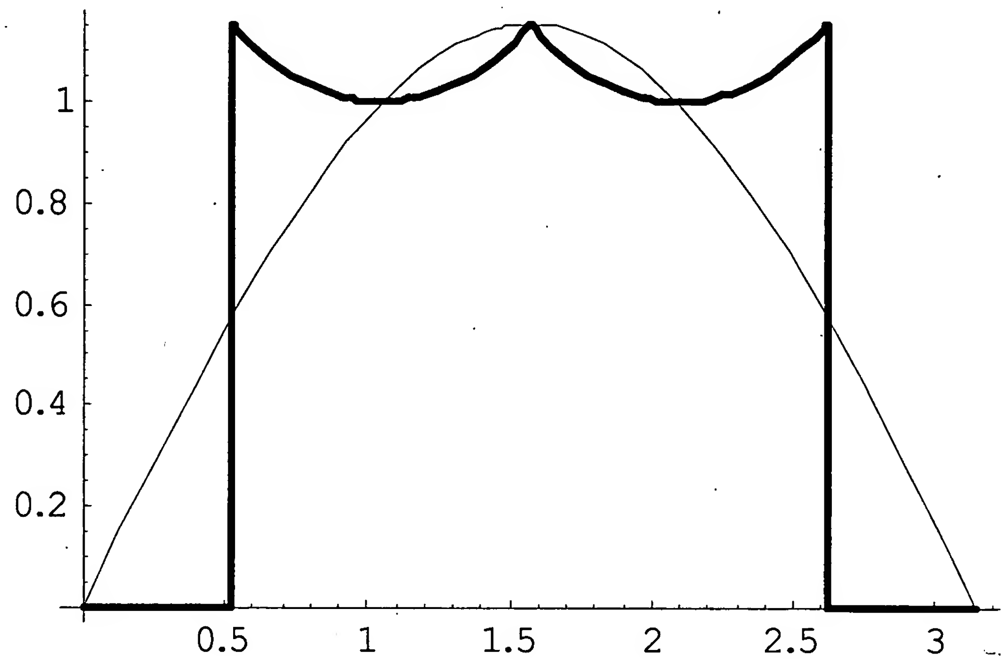


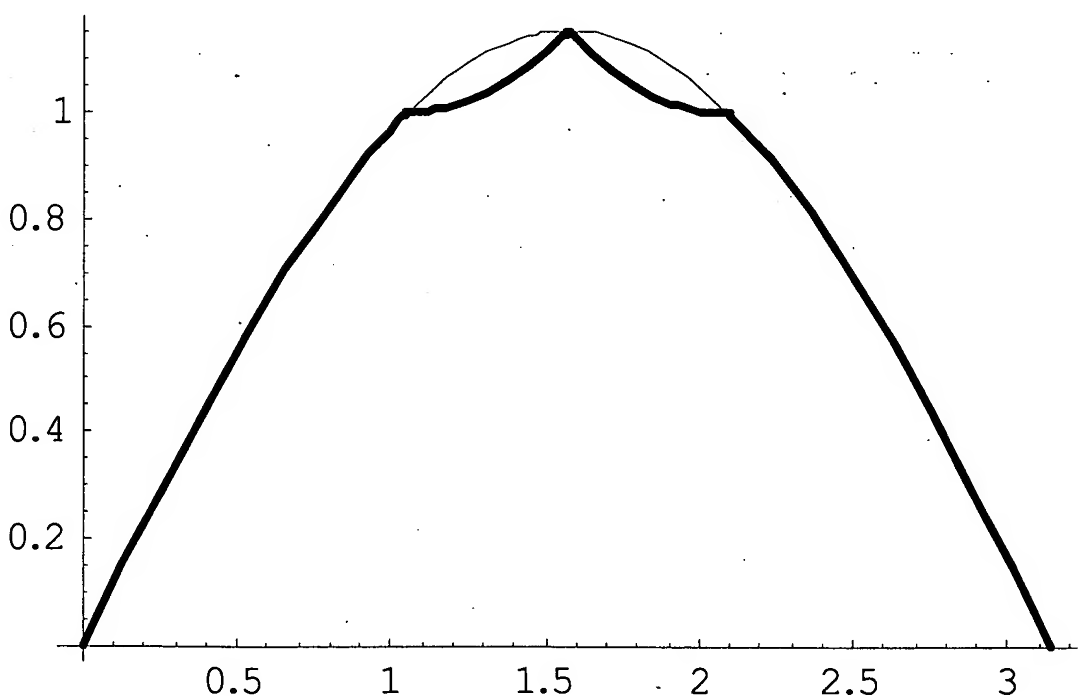
FIG. 6



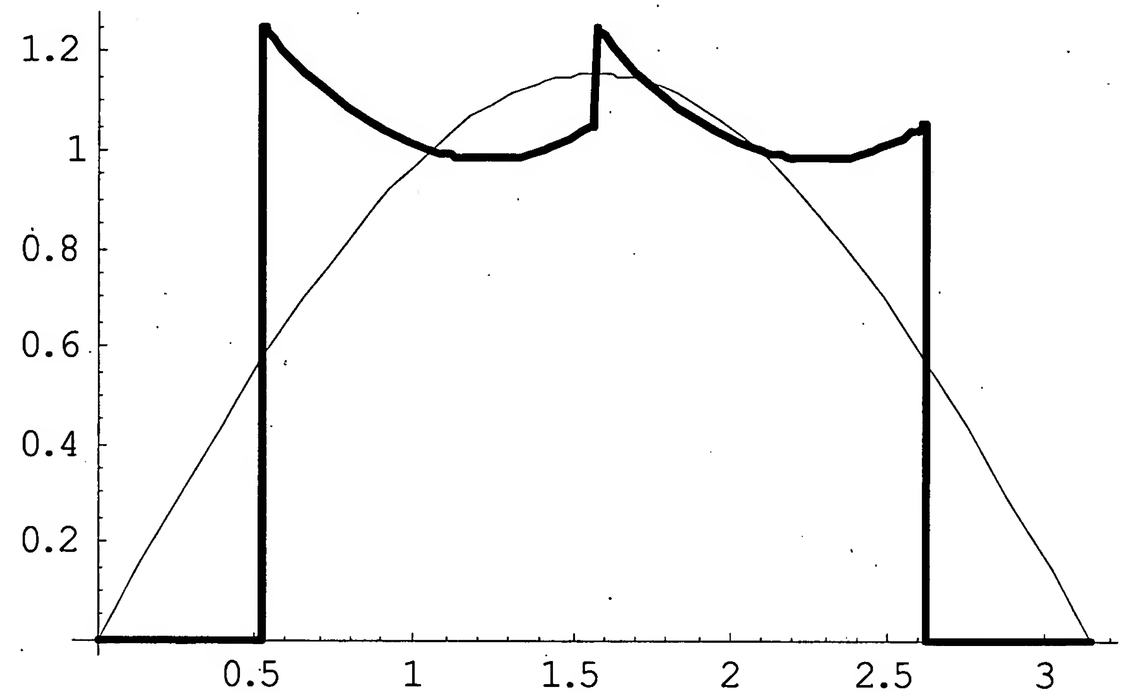
FIG> 7



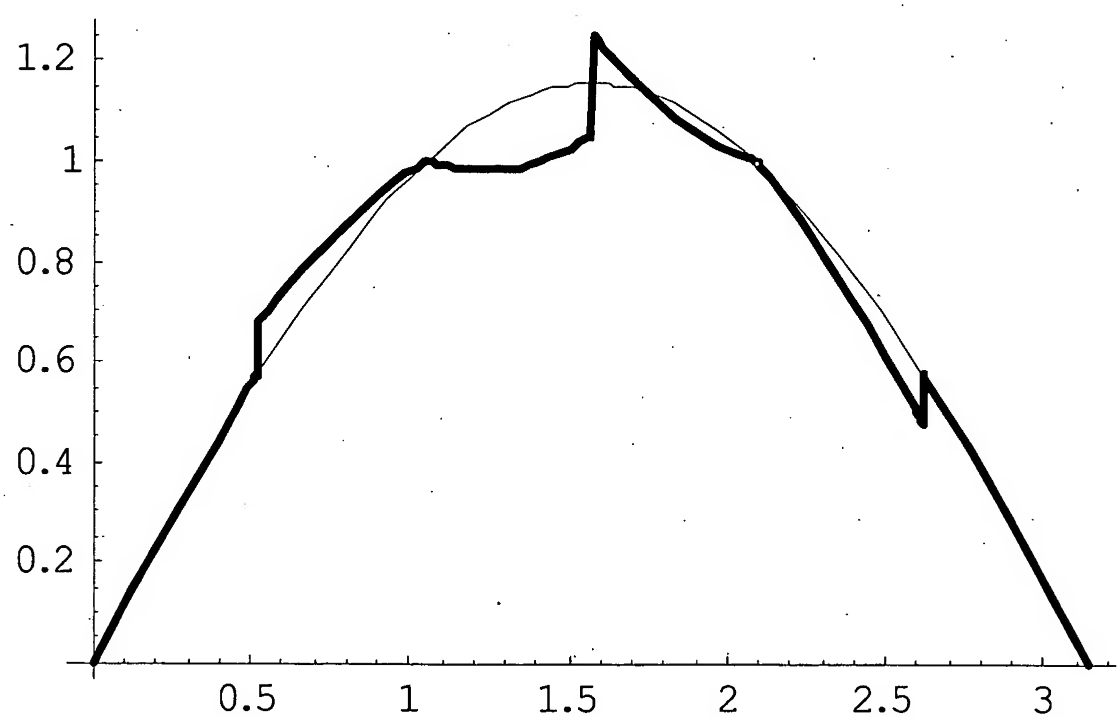
FIG> 8



FIG> 9



FIG> 10



FIG> 11

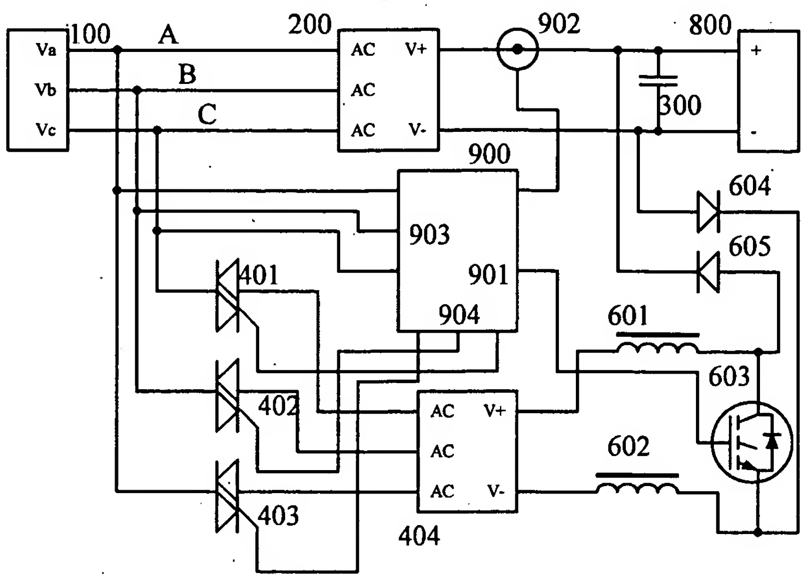


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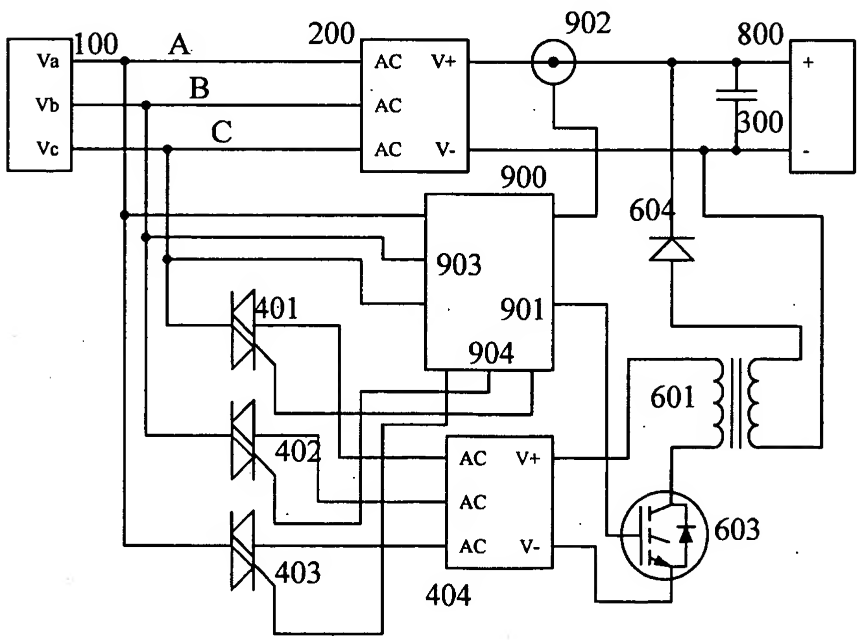
FIG. 12



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LOWER INTER-PHASE RECIFIER BOOST CONVERTER PARALL COMPENSETING THREE-PHASE POWER FACTOR CORRECTION

TECHNICAL FIELD OF THE INVENTION

The present invention is directed, in general, to three-phase active power factor correction (APFC), more specifically, to a parallel feed-forward compensation three-phase APFC.

BACKGROUND OF THE INVENTION

Recently, the harmonic current injecting into the main line from rectifier loads, which share more and more, has been becomes one of the common circumstance problem. It is the basement and will dominate the research and design in this field that the harmonic distortion emission of a electrical equipment, its performance commonly is regular and can be foreboded, is easier to be processed comparing with it after emitting into the main line and becoming random.

No doubt that the active power factor correction (APFC) is the best way to solve the problem. After several years of efforts, for low power and single phase power supply the APFC technology has been getting successful, and a lot of products have been assembled APFC units, but for three phases high power supplies no match products are put into market because of effective and cost, although a lot of patents and papers having been published. Most of the schemes of three-phase APFC are boost circuits, which force the phase current waveform in the shape of sine. Usually it makes the power supply have to process double amount of power, obviously, it will much increase the cost and decrease the efficiency. Reducing the power processed by APFC is the key problem.

American patent 5,886,891 disclosed a three-phase boost converter with low input current total harmonic distortion (THD). The boost converter includes first, second and third inductors coupled to the first, second and third phase inputs, respectively. The boost converter further includes first and second third capacitors coupled between the first, second and third phase inputs, respectively, and a node between two boost switches. The first and second switches cooperate progressively to employ a voltage across the rails less a voltage across the first, second and third capacitors to discharge currents through the first, second and third inductors, respectively, and thereby reduce input current total harmonic distortion (THD) on all three of the phase inputs.

American patent 6,043,997 disclosed a three-phase boost converter having an auxiliary stage boost converter.

Both of them get some successful to decrease the total power processed while reduce input current total harmonic distortion, but it is not enough and further more the output voltage of the rectifier is still much higher than common rectifier.

Accordingly, what is needed in the art is that, the boost converter is as simple as possible, the total power processed is as less as possible and the output voltage is maintained as common rectifier while reducing input current total harmonic distortion (THD) to a preferable range.

SUMMARY OF THE INVENTION

To meet the needs mentioned above, an invention called parallel lower inter-phases rectifier compensation mode (PLPRC) three-phase power factor is presented.

The gap and the jumps at each edge of phase current waveforms at interval between $\pm\pi/6$ across zero are the main reason making harmonic distortion.

In the present invention, an auxiliary circuit composed of a lower inter-phase rectifier and a boost converter is paralleled with a common three-phase rectifier. To each $\pi/6$ interval, in the auxiliary circuit, of the two phases at same polarity, one with lower absolute value is forced to conduct to the third phase by cutting-off one with higher absolute value.

In this way, in each $\pi/6$ interval for the two at same polarity of the three phases, the phase with lower absolute value is forced to gave out the current with suitable waveform in its current gap before, the current of the phase with higher absolute value is decreased and its waveform becomes more close to sine waveform, only the input current of the third phase is maintained as it is before.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, reference is now made to the following descriptions taken in conjunction with the accompanying

drawings, in which:

FIG.1 illustrates a schematic diagram of the invention.

FIG.2 illustrates the phase relationship of common three-phase main line power supply.

FIG.3 and FIG4 illustrate a possible current waveforms selected to be forced by boost converter.

FIG.5 and FIG6 illustrate the output voltage and current waveforms of a three-phase low filtering capacitor rectifier with constant power load, which are normalized by the magnitude of phase peak voltage and output power.

FIG.7 and FIG8 illustrate the phase current waveforms no and with APFC, that the filtering capacitance is negligible.

FIG9 and FIG10 illustrate the phase current waveforms no and with APFC, that normalized filtering capacitance is 0.2 (by phase peak voltage and output power, period is 2 π)

FIG11 and FIG12 illustrate two embodiment of the invention.

DETAILED DESCRIPTION

Referring initially to FIG.1, illustrated is a schematic diagram of a parallel lower inter-phases rectifier compensation mode (PLPRC) three-phase power factor correction circuit. In one embodiment, it includes three-phase input 100 and the rectifier output 800, a common three-phase bridge rectifier 10 with low filtering capacitance and, in parallel with it, an auxiliary boost circuit 20 with a lower inter-phase rectifier. The common three-phase bridge rectifier 10 includes three-phase rectifier bridge 200 and filtering capacitor 300. In parallel with 10, the auxiliary boost circuit 20 includes a lower inter-phase rectifier 400 and a boost converter 600. The lower inter-phase rectifier 400 includes three bi-direction switches 403, 402 and 401 to cut off phase A, B and C respectively, and another three-phase rectifier bridge 403. The boost converter 600 includes inductor 601and 602, boost switch 603, diode 604 and 605.

FIG.2 illustrates the phase relationship of common three-phase main line power supply.

A switching power supply with constant current or constant voltage output is a constant load for three-phase capacitor filtering rectifier. The FIG.5 and FIG.6 show the output voltage and current waveforms of a capacitor filtering three-phase rectifier with constant load and low capacitance respectively. The phase current waveforms are shown in FIG.7, the capacitance is negligible, and in FIG.9, the normalized magnitude of capacitance is 0.2 (normalized by the magnitude of phase peak voltage and output power, period is 2 π) respectively. It is obviously that the gap and the jumps at each edge of phase current waveforms at interval between ± π/6 across zero are the main reason made harmonic distortion.

In our invention, a whole period of three phase is divided into 12 parts, as shown ab, bc, cd, ……kl and lm as shown in FIG2. In each part, there are two phases at same polarity, the phase with higher absolute value is cut-off, then the phase with lower absolute value is forced to conduct to the third phase and gave out the current to output 800 with suitable waveform through the boost converter. For instance, in the bc interval, the phase A is cut-off by 403, the phase C and phase B are rectified by 404, the boost converter 600 forces the current waveform injecting into the output 800 to be suitable. In this way, the phase C has suitable current waveform in its current gap before, the current of phase A is decreased and its waveform becomes more close to sine waveform, only the input current of phase B is maintained as it is before.

Here are two examples.

The current waveform injecting into the main rectifier forced by the boost converter 600 is the corresponding part of sine waveform, as shown in FIG.9 and FIG.10, which magnitude is determined to make the waveform continuous at the points ± π/6 cross zero. For the negligible magnitude of the filtering capacitor 300, the waveform is shown in FIG.8, and if the normalized magnitude filtering capacitance is 0.2, the waveform is shown in FIG.10. For these two examples, the numerical analysis shows that their THD are decreased from 0.313and 0.306 to 0.030 and 0.063 respectively. All of them are far below IEC1000-3-2.

The average power of the auxiliary circuit is only:

$$P_a=(6/\pi \mathrm{Sin}(\pi/3) \int_0^{\pi/6} \mathrm{Sin}(t)\mathrm{Sin}(t+\pi/6)\,dt$$
$$=0.224$$

The normalized conditions of the filtering capacitor magnitude are that, the magnitude of phase peak voltage is 1, the output power is 1, the period is 2 π, so that the normalizing factor is

$$\frac{wV^2}{N}$$

Where N is output power, ω is cycle frequency, and V is magnitude of phase peak voltage. For instance, if the

magnitude of 50Hz three phase electricity phase peak voltage is 540V, and the output power is 10KW, then the normalized magnitude of filtering capacitance 100 μ F is 0.092.

If the load of three-phase capacitor filtering rectifier is a pure resistance or inductance load, the PLPRC APFC is effective also.

FIG11 and FIG12 illustrate two industrial specific embodiments of the PLPRC APFC. Here three TRIAC are used as bi-direction switches, and an IGBT is used as boost switch. In any interval only one of two inductors 601 and 602 is working as a boost inductor, while the cross voltage of the other inductor is zero. As shown in FIG2, at the a, c, e, g, i, k, m points, the forced waveform of the current cross zero, the states of the inductors 601 and 602 turn each other; then at the b, d, f, h, j, l points, the state maintain and the inductor at the boost up voltage state is in series with the TRIAC to be switched off, it makes the process easer.

A control circuit 900 is included, it gets the phase and output current information from 903 and current sensor 902, then gives out control signals to switches 401, 402, 403 and IGBT 603. In FIG12 a transformer converter is used to instead of the boost converter, and it is obviously that the output of the transformer 601 can be connected to the output of whole switching power supply. Besides flyback,

Although the present invention has been described in some detail, those skilled in the art should understand that they can make various changes, substitutions and alterations herein without departing from the spirit and scope of the invention in its broadest form.

What is claimed is:

1 A parallel, feed-forward, compensation three-phase active factor correction circuit having a common three-phase bridge rectifier with low filtering capacitance, that the normalized magnitude is less than 0.5, and optimum, less 0.2; (by phase peak voltage and output power, period is 2π) in parallel with said rectifier, having an auxiliary boost circuit, which has only single boost cell but not three, which changes only the distribution of the input current between phases, which can be manufactured as a independent element.

2 Parallel, feed-forward, compensation three-phase active factor correction circuit as recited in claimed 1 wherein a common three-phase rectifier bridge and, connected with its output, a filtering capacitor compose the main rectifier. Three bi-direction switches connecting with three phase input lines and another three-phase rectifier bridge, its three input tips connect with said three switches, compose a lower inter-phase rectifier. The lower inter-phase rectifier and, connecting with its output, a boost converter, which has only single boost cell and its output connecting with the output of said main rectifier, compose said auxiliary boost circuit.

3 Parallel, feed-forward, compensation three-phase active factor correction circuit as recited in claimed 2, in said lower inter-phase rectifier, a whole period of three phases is divided into 12 parts according to which two phase being at same polarity. In each $\pi/6$ interval, said switches, in turns, cuts off one with higher absolute value of the two phases being at same polarity, then one with lower absolute value is forced to conduct to the third phase and giving out the current to said boost converter.

4 Parallel, feed-forward, compensation three-phase active factor correction circuit as recited in claimed 2and 3, the said boost converter includes a boost switch, but two boost inductors and two diodes. Said boost converter forces the current from said lower inter-phase rectifier injecting into the output of said main rectifier and with suitable waveform. In this way, of the two phase being at same polarity the one with lower absolute value has suitable current waveform in its gap before, the current of one with higher absolute value is decreased and its waveform is more close to sine waveform.

5 Lower inter-phase rectifier as recited in claimed 2 and 3, said bi-direction switches can be TRIAC or IGBT and diodes or GTO and diodes etc. electronic components.

6 Parallel, feed-forward, compensation three-phase active factor correction circuit as recited in claimed 2and 3 having a control circuit which gets the information of phase and output current magnitude from current sensor to control said bi-direction switches and boost switch.

7 Said boost converter as recited in claimed 4, an insulated (such as flyback) converter can be used to instead of the boost cell, and its output can be connected to the output of whole switching power supply directly.